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RFID PREVENTIVE MAINTENANCE AND TROUBLESHOOTING (PREPRINT)

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14. ABSTRACT
RFID installations consist of a large number of interdependent and interconnected components that function together as a unit for proper functionality and operations of the system. These components include tags, readers, antennas, networks, computing systems, power supplies, and peripherals, accessories and other mechanical systems that are controlled by the RFID implementation. Current RFID hardware is still relatively delicate and no two implementations are exactly the same. Even after an RFID system is has been successfully installed, there is a possibility that it will face various performance-related issues, including reader failure, tag failure, or problems with the middleware. In order to track, predict, and prevent performance problems, the system will need to be closely monitored. This report concentrates on two primary areas to be monitored: (i) monitoring of basic system status, and (ii) monitoring the overall system behavior.

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RFID Preventive Maintenance and Troubleshooting

Background:

RFID installations consist of a large number of interdependent and interconnected components that function together as a unit for proper functionality and operations of the system. These components include tags, readers, antennas, networks, computing systems, power supplies, and peripherals, accessories and other mechanical systems that are controlled by the RFID implementation.

The advantages to RFID technology are great; however current RFID hardware is still relatively delicate and no two implementations are exactly the same. Even after an RFID system is has been successfully installed, there is a possibility that it will face various performance-related issues. These issues can include reader failure, tag failure, or problems with the middleware. With a myriad of different hardware options maintaining RFID system at an effective operational level can be tricky, especially when a problem occurs. For companies utilizing RFID, hardware failure can be disastrous, late orders, mismanaged inventory, or the grinding halt of an assembly line can prove costly to companies.

In order to track, predict and prevent performance problems, the system will need to be closely monitored. Monitoring read rates and other performance measurements can help you determine when a problem is occurring and aid you in your troubleshooting efforts. While most RFID reader manufacturers provide basic troubleshooting guides for their products, such guides are typically very specific to specific devices and models, or they are too advanced or low level for troubleshooting a complete installation. The goal of this report is to provide a generalized monitoring and troubleshooting guide that will allow individuals of different skills to determine problem areas and potentially fix current issues or prevent potential future problems. A final goal of this project (beyond the scope of this report) is to create an information repository of common problems that face RFID reader, regardless of manufacturer, and provide solutions to these problems in a simple user-friendly form.

We concentrate on two primary areas to be monitored: (i) monitoring of basic system status, and (ii) monitoring the overall system behavior. Monitoring the basic status is a method that helps troubleshoot and prevent problems with data collected by the RFID system. Monitoring the system behavior is a way to monitor the system by gathering reader statistics. There are several ways to achieve this, including monitoring the reader by either using the ping command or by using the Simple Network Management Protocol (SNMP). Another way to gather reader statistics is by measuring the system behavior by intrusive monitoring; which can be done by issuing commands to the reader to gather information about its internal operations, or by analyzing the information provided by the reader. While intrusive monitoring is possibly the most accurate method of obtaining information on a reader, a potential downside of this method is that the reader will potentially be unavailable during the monitoring process, affecting its normal operations. To avoid such problems, readers can be monitored using

non-intrusive monitoring methods, which do not send commands directly to the readers, but coordinate with the middleware systems to extract reader performance metrics. Of course, designing such non-intrusive monitoring methods can be tricky because of the potentially proprietary nature of the middlewares being used.

There are several theoretical and statistical methods that could be useful in analyzing read rates; they can also show patterns in behaviors of the system and help graph the flow of tags. Average tag traffic volume is a measurement that helps you understand the flow pattern of the tags through the RFID system. Finding the ratio of read errors to total reads can help locate problems dealing with faulty tags, antennae, network connections, improper placement of antennas, improper tag types, signal interferences, or even low signal strength. The read error change rate can be used to determine the stability a system, and can also be used to identify some problems related to the reader's performance. Comparison between the actual tag traffic rate to the predicted tag rate can be helpful to detect anomalies in the performance characteristics of the readers. The expected failure rate over time can also be measured by using the failure rates of individual RFID components. This metric, typically known as the mean time between failures (MTBF), can help determine how reliable the system is. The data for these metrics can be acquired using intrusive or non-intrusive collection strategies. Many middleware programs and RFID software will automatically keep track of this data.

When installing an RFID system it is important to remember that the readers can only read items from a certain distance. Also readers can fail if the tags are improperly placed on items. Multiple readers may have to be set up and configured differently for different applications. When you are trying to diagnose reader failure, some things you need to check are the communication between the reader and the software application, the type and number of antennas being used, the type of tags, the firmware versions, errors in codes and power output, the positioning of the antennas and the position of the tags in the RF field, the power setting for each antenna, the antenna gain, and the length of the cables.

When trying to troubleshoot common antenna issues there are several possible solutions. If there is no signal reception, and the power and system connections are working, it is possible that either the RF cable has incorrect termination, or is may be improperly connected or even it has excessive transmission loss, or the antenna polarity of the receiving antenna is the reverse of the transmitting antenna. If your reader cannot communicate with the tag due to poor signal strength, you will need to check to make sure that all of the connections and cables are tightly attached. Irregular signal changes during the transmission and the reception can be the result in interferences from other equipment or possibly metal in the interrogation zone, or even there are multiple antennas on the same polarity.

System hardware failure can be caused by the firmware not being upgraded, damaged equipment, or equipment incompatibility. The firmware will need to be upgraded often, because RFID is still a growing and

developing technology and is changing every day. Some of the RFID equipment can easily be damaged, so you need to be careful where you are placing it in your operations. Some antennas can read only a certain type of tag, so you have to look and see what kind they are designed for. Matching antenna gain with transmission line loss is another important step when you are setting up your RFID system.

Since tags can be easily damaged, they can be interesting to troubleshoot. The problems can range from nonfunctioning tags to environmental conditions, such as temperature and humidity, and even interference. One major concern when you use tags it the release of electrostatic discharge, this can fry out the chip or even melt it. The integrated circuit can also be dislocated, if the silicon bonds in the semiconductor break due to stress or when an unexpected expansion within the silicon wafer takes place due to a sudden rise in temperature. Another possible problem is tag detuning, this can happen when several tags are being read in the same area, when metal and different dielectric mediums are near the tags, and a shift in resonance frequency from the operating frequency. Ways to protect your RFID system from electrostatic discharge is to ground your equipment and use air ionizers.

If you are either loosing a lot of tags or have a high tag failure rate this could be bad for your business operations and can also show that you are having problems. You can help prevent these from happening by using proper tag management techniques. The main tag management techniques are voiding tags, replacing tags, and data management systems. By using the kill command you can permanently disable or void tags, and when you find that you have a non-working tag you should replace it. You should also have a good way to track if your tags are being read to assure accuracy.

Many business operations have generated the demand for RFID technology to be connected to each other on isolated EPC networks in order to create a global RFID network. Middleware plays an important role in managing data and devices, while also providing strategic opportunities and functions. You must be able to make sure that your middleware can handle the scale of your operations, while also providing the correct security features. The network must also be able to handle the scale of what you need to use it for. Most RFID systems have at least one Reader Network Controller, which provides control and data-path interface to a reader network. The Simple Lightweight RFID Reader Protocol is a protocol that is used in an IP-based network to send and receive information on configuration, control parameters, status, and tag from readers. RFID readers can help manage network traffic; they can also act as a gateway between an IP network and the tags.

As companies today are spending more resources to research and implement RFID solutions, issues such as a preventative means to stop problems from ruining a project, increasing monetary costs, plus the over burdening the company with a lack of ROI are becoming more important. In addition, academic universities, like Wright State, could use some troubleshooting assistance for students learning RFID concepts in a lab environment. With this in mind, plus the RFID knowledge imparted in the

aforementioned discussion, this MIS480 team has created a troubleshooting guide that hopefully will be useful in solving many a persons' problem over time.

The primary purpose of this report is to aid RFID integrators, system administrators, and end-users with a guide to answer the following two questions, and provide a generalized method for reaching a solution.

I. Has a failure occurred?

The best way to see if a component has failed is to continuously monitor it and check if it is not working properly. The two main ways to monitor are monitoring the basic status and monitoring system behavior. Monitoring the basic status uses a feedback system to notify the operator whether a read has been successful and how to respond to unsuccessful reads. Ways to monitor system behavior are by using data that has been gathered by read rates and read accuracy.

II. What can cause a failure?

The main ways that system hardware can fail are caused by not updating the firmware, equipment failures, or equipment incompatibility. Since tags are small and fragile they can be easy damaged just by moving then in a warehouse. Tags can also be damaged by static charges, IC dislocation, or detuning. Even with everything else properly working you can have a problem with the RFID middleware software. Your system must be able to handle the scale of your operations; it must also have the correct security features set up. You must also be aware that your network may cause some problems with your RFID setup. Other things that may cause failure are the placement of metal or water near your RFID setup.

Solution Questionnaire

As a guide to the type of issues that need to be resolved in order to monitor, troubleshoot, and prevent issues with the RFID implementation, the administrative personnel will need to systematically answer several questions that will either lead to solutions or other questions that need to be answered. A set of such questions is presented below. These questions provide a reasonable complete set of troubleshooting guidelines, and will provide the troubleshooter with a roadmap towards a solution to a current problem or the prevention of a potential problem with the system. For the purpose of clarity, we have divided the questions into 9 sections: (i) general questions addressing basic monitoring issues, (ii) environmental questions addressing issues with the interrogation zone, antenna related questions to address problems with antennas, (iv) network-related questions to address issues with the network, (v) tag-related questions to address problems with tags, (vi) metrics-based questions to address complex problems with interaction, (vii) middleware/code related questions to address software issues, (viii) cable-related questions to address problems with cables, and finally (ix) miscellaneous questions to address anything not covered in the other sections.

I. General Questions

1. What has the past behavior of the reader been like before it failed?
2. Does the reader directly face another reader?
3. How focused or narrow is the read beam?
    a. A higher antenna gain plus link margin will occur if the beam is more focused and narrow.
4. Does the reader have any physical damage symptoms that may indicate that it isn't working correctly?
5. How old is the reader and when was the last time you replaced the antennas and cables?
    a. Return Material Authorization records
6. Has the reader been properly grounded to prevent damages that electrostatic discharge may cause?
7. Does restarting the reader restore its ability to operate?
8. Has your reader been intentionally or unintentionally bumped around or knocked out of place?
9. Has the reader been grounded to the same point as the rest of the RFID system components?
10. Are the reader settings configured properly?
11. Does the reader indicator glow?
12. Was the reader and antennas installed properly?

II. Environment Questions

13. Are there any nearby devices that may have interfering frequencies that would cause the reader to not function properly?
14. What kinds of read unfriendly materials are around? (ex. Metal or water)
15. Is the Fresnel zone, or propagation path that the signal takes through the air blocked or obstructed?

III. Antenna Related Questions

16. Is the power level that feeds the antenna high enough to enable a proper read?
17. Are the proper antennas attached and are the tags you are trying to read aligned properly?
18. Do the RFID tags plus readers have their antennas on the same pole? (ex. Horizontal polarized antenna or vertically polarized antenna)
19. Are the reader antennas positioned at all necessary points to where a tag may show up?

IV. Network Related Questions

20. Is the reader properly attached to the network and is it capable of communicating with the tag?
    a. May want to use the ping command or SNMP.
21. Are proper software and network processors installed to enable RFID readers to handle network traffic?

V. Tag Related Questions

22. Are you using the appropriate tag types with the prospective item you are trying to read?
23. Are the tagged items out of range of the reader?
24. Has the tags been properly placed on the item?
    a. If not, reader failure could occur.
25. Since UHF and Microwave frequencies focus on reading the far field whereas LF and HF focus on reading the near field, is the tag turned properly to the antenna?
26. Is there an instance that the reader hasn't failed but that the tags have?
27. Does the item in which you are reading have enough dwell time in the interrogation zone?

VI. Metrics-based Questions

28. Has there been a steady increase or fluctuation in the read error change rate?
    a. This may indicate a fault in either the design of the system or in the hardware.
29. What kinds of results are being produced by formulas such as the actual versus predicted traffic rate?
    a. APTR values can be used to detect anomalies in the performance characteristics of readers.
30. Was the link margin or some of the RFID equipment losses/gains calculated correctly?
    a. These calculations improperly figured could lead to improperly tuned antennas and thus reader failures.

VII. Code/Middleware Questions

31. Is your program code that triggers the read as you really want it?
32. Is the RFID software status indicator on the computer screen indicating read errors?
33. Is the RFID middleware not properly monitoring RFID reader network traffic or filtering useful information?
34. Are the I/O devices and reader software functioning properly?
    a. If not, they may indicate that the reader is not functioning properly when it really is.
35. What was the last time the reader firmware software was upgraded?

  a. In terms of ISO standards, the software/hardware may no longer be compatible.

  b. According to best practice, when purchasing readers, one must make sure that the item is forward compatible with what may be coming out and that the reader contains a digital signal processor chip which is upgradeable.

36. Is the RFID middleware appropriate for the system?

  VIII. Cable/Accessory Questions

37. Have you changed the cable length, connector, adapters, or environmental conditions to where the RFID system signal is reduced?
  a. Bandwidth is reduced and transmission is delayed by lengthening a transmission line.
  b. Doubling the length of cord doubles the attenuation.
  c. Data transmission at higher frequencies can be prevented with higher attenuation in transmission lines.

38. Is the reader equipment compatible with the rest of the RFID system components?

39. Is the connection medium between the reader and host operating/functioning properly?

40. Has the power supply died?

41. Have you used a spectrum analyzer to test for path loss and verify the strength of the interrogation zone RF field?

42. Do you have the right power supply for the reader?

  IX. Miscellaneous Questions.

43. Have you ever done a site survey prior to the installation of the RFID system to help identify and eliminate interference effects in an environment?

Troubleshooter Implementation

Based on the above questionnaire, and a rudimentary dependency characterization of the questions, a basic troubleshooting wizard is currently being prototyped to test the feasibility of the approach. The initial tests with this prototype show the viability of such a system. To be successful, the a more intelligent system capable of weighting the questions to determine the "correct" sequence of questions need to be developed, which is beyond the scope of this report. However, for the reader's curiosity, some screen shots of this wizard are shown below:
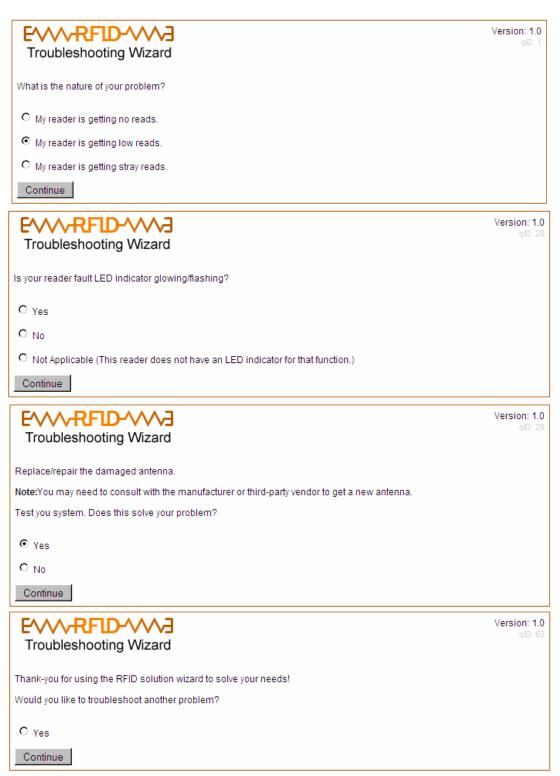
Fig. 1. Screenshots from the troubleshooting wizard prototype

Summary

The initial experiments with the prototype and troubleshooting of real hardware at the RFID lab at the Raj Soin College of Business show the feasibility of this methodology and potentials of an actual implementation.

Bibliography

Loftware RFID Reader Solutions User's Guide. Version 2.x. Visited through Google on
4/12/2007. http://loftware.com/documents/rrm/rrm.pdf

RFID Switchboard Visited 4/15/2077
http://www.rfidsb.com/

Unit 10: Monitoring and Troubleshooting. CompTIA RFID+ Certification. Boston:
Thomson
Course Technology, 2006.

Wiesenfield, Ira and Robert Smith. "Antenna System Troubleshooting Simplified."
Mobile
Radio Technology. Visited 4/15/2007.
http://mrtmag.com/mag/radio_antenna_system_troubleshooting/

Sirico, Louis. "Tag It Right!" RFID Wizards.com. Visited 4/15/2007.
www.rfidwizards.com